The mathematics of why our grandmothers love us

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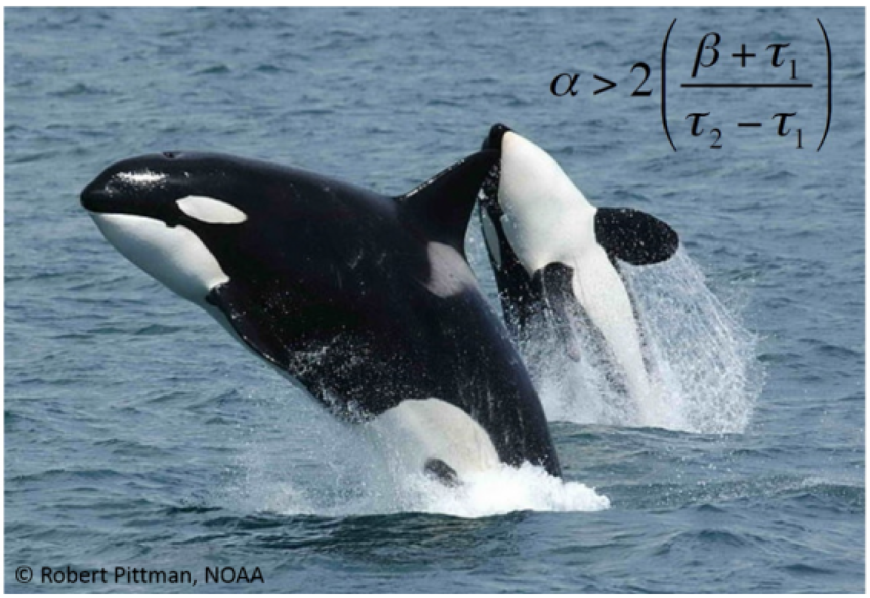

Credit: Oxford Science Blog

Based on the strong reactions that it provokes from people, it would be fair to say that mathematics has an image problem.

Maths is one of the few skillsets, unlike reading for example, that people are not embarrassed to admit they do not possess. Class room memories of daunting equations and fractions with no immediate resonance to the real world, scare people into declaring they are frankly, "rubbish at maths".

In reality, mathematics underpins the world around us in more ways than we could ever imagine. Just by paying bills, measuring home improvements and making everyday decisions, people do maths, often without realising.

Our new Scienceblog series will tackle these preconceptions, highlighting the role that maths plays in shaping our understanding of science, nature and the world at large.

In the first of the series, Michael Bonsall, Professor of Mathematical Biology at the Oxford University Department of Zoology, discusses his research in population biology, and what it tells us about species evolution and why grandmothering is important to humans.

What is mathematical biology?

It is easy to get lost in the details and idiosyncrasies of biology. Understanding molecular structures and how systems work on a cellular level is important, but this alone will not tell us the whole science story. To achieve this we have to develop our insight and understanding more broadly, and use this to make predictions. Mathematics allows us to do this.

Just as we would develop an experiment to test a specific idea, we can use mathematical equations and models to help us delve into biological complexity. Mathematics has the unique power to give us insight in to the highly complex world of biology. By using mathematical formulas to ask questions, we can test our assumptions. The language and techniques of mathematics allow us to determine if any predictions will stand up to rigorous experimental or observational challenge. If they do not, then our prediction has not accurately captured the biology. Even in this instance there is still something to be learned. When an assumption is proven wrong it still improves our understanding, because we can rule that particular view out, and move on to testing another.

What science does this specialism enable – any studies that stand out, or that you are particularly proud of?

Developing a numerate approach to biology allows us to explore, what at face value, might be very different biologies. For instance, the dynamics of cells, the dynamics of diseases or the behaviour of animals. The specialism allows us to use a common framework to seek understanding. The studies that stand out in my mind are those where we can develop a mathematical approach to a problem, and then challenge it with rigorous, quality experiments and/or observation. This doesn't have to happen in the same piece of work but working to achieve a greater understanding is critical to moving the science forward.

You recently published a paper: 'Evolutionary stability and the rarity of grandmothering', what was the reasoning behind it?

Grandmothering as a familial structure is very rare among animals. Whales, elephants and some primates are the few species, besides humans, to actually adopt it. In this particular study we took some very simple mathematical ideas and asked why this is the case.

Evolution predicts that for individuals to serve their purpose they should maximise their reproductive output, and have lots of offspring. For them to have a post-reproductive period, and to stop having babies, so that they can care for grandchildren for instance, there has to be a clearly identified benefit.

We developed a formula that asked why grandmothering is so rare in animals, testing its evolutionary benefits and disadvantages, compared to other familial systems, like parental care and co-operative breeding for instance, (When adults in a group team up to care for offspring). We compared the benefit of each strategy and assessed which gives the better outcomes.

What did the findings reveal about the rarity of grandmothering and why so few species live in this way?

Our maths revealed that a very narrow and specific range of conditions are needed to allow a grandmothering strategy to persist and be useful to animals. The evolutionary benefits of grandmothering depend on two things: the number of grandchildren that must be cared for, and the length of the post-reproductive period. If the post-reproductive period is less than the weaning period (the time it takes to rear infants) then grandmothers would die before infants are reared to independence.

We made the mathematical prediction that for grandmothering to be evolutionary feasible, with very short post-reproductive periods it is necessary to rear lots of grandchildren. But if this post-reproductive period is short, not many (or any) would survive. Species with shorter life spans, like fish, insects and meerkats for instance, simply don't have the time to do it and focus on parental-care. Evolution has not given them the capability to grandparent, and their time is better spent breeding and having as many offspring as they can. By contrast long-lived animals like whales and elephants have the time to breed their own offspring, grandparent that offspring and even to great-grandparent the next generation.

How do you plan to build on this work?

Although grandparenting isn't a familial strategy that many species are able to adopt, it is in fact the strongest. Compared to parental-care and co-operative breeding, grandparenting has a stronger evolutionary benefit – as it ensures future reproductive success of offspring and grand-offspring – giving a stronger generational gene pool.

Moving forward we would like to test mathematical theories to work out if it is possible for species to evolve from one familial strategy to another and reap the benefits. Currently for the majority of species rearing grandchildren instead of having their own offspring is not a worthwhile trade-off.

What are the biggest challenges?

Ensuring that the mathematical sciences has relevance to biology. Biology is often thought to lack quantitative rigour. This would be wrong. The challenge is to show how the mathematical sciences can be relevant to, and help us to answer critical questions in biology. This will continue to be a challenge but will yield unique insights along the way in unravelling biology.

What do you like most about your field?

So many things. Firstly, the people. I work with a lot of very smart people, who I look forward to seeing each day. I also get to think about biology and look at it through a mathematical lens. Finally I think the specialism allows us to do fantastic science that has the potential to improve the world.

Is there any single mathematical biology problem that you would like to solve?

Developing a robust method to combine with biological processes that operate on different time scales - as this would have so many valuable, and to use one of my favourite words, neat, applications to our work.

Why did you decide to specialise in this area?

Because of the perspective that we can gain from it and because I love biology and maths. Unpicking the complexities of the natural world with maths and then challenging this maths with observations and experiments is super neat. And I can do (some of this) while eating ice-cream!

More information: Jared M. Field et al. Evolutionary stability and the rarity of grandmothering, *Ecology and Evolution* (2017). DOI: 10.1002/ece3.2958

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